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EFFECTS OF IN-STREAM MINING ON CHANNEL STABILITY

Volume II - Final Report

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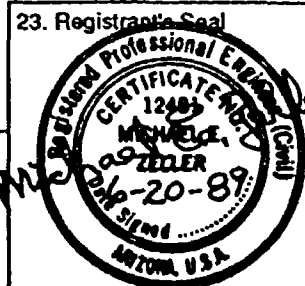
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16. Abstract <p>This report presents a comprehensive treatment of the technical and non-technical issues related to the impacts of in-stream sand and gravel mining upon the stability of river systems in Arizona. All major categories are addressed, including such areas as: regulatory practices, structural hazards, economic value, social and environmental factors, statewide classification of streams, review of methodologies, mitigation measures, engineering parameters, long-term procedures, short-term procedures, river response simulation procedure, case histories, justification for regulation, implementation plan, and recommendation for further monitoring and data collection. The physical processes associated with sand and gravel mining and the impacts of sand and gravel mining on the streams, rivers, and riverine structures are documented. The concepts, theory, and experience of the team have been incorporated in this report in the form of written material and mathematical models. Methods have been formulated and presented for evaluating both short-term and long-term response of sand and gravel mining on river behavior, bridges, and associated river control structures. The necessity for sand and gravel mining, the impacts of sand and gravel mining, regulatory procedures adopted by other states, the short- and long-term interests of the sand and gravel mining industry, and recognition of the fact that the sand and gravel mining industry is vital to the well-being of the State of Arizona all contribute to the justification for regulation. The final section of the study deals with the strategy and formulation of legislative action that could be implemented to better control sand and gravel mining in the State of Arizona.</p> <p>Executive Summary, Volume I Appendices, Volume III</p>			
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FOREWORD

This is to report that I have worked closely with Simons, Li & Associates, Inc. in their effort to achieve the objectives outlined by the contract awarded by the Arizona Transportation Research Center through the total period of investigation and analysis. I have been involved with and have carefully reviewed their work considering all major categories including such areas as: regulatory practices, structural hazards, economic value, social and environmental factors, statewide classification of streams, review of methodologies, mitigation measures, engineering parameters, long-term procedures, short-term procedures, justification for regulation and model legislation. The quality of the effort leading to preparation of the final report, in my opinion, has been excellent. The report is based upon many years of experience by a group of professionals that have worked diligently with watersheds, rivers and mining to better understand the physical process, the necessity for sand and gravel mining, the impacts of sand and gravel mining, regulatory procedures as adopted by other states, the short and long-term interests of the sand and gravel mining industry, and recognition of the fact that the sand and gravel industry is vital to the well-being of the State of Arizona. Also, the project benefitted from other past related work done in the sand and gravel mining area by Simons, Li & Associates, Inc. and by D.B. Simons of Simons & Associates.

It is obvious from the review of past work and the final report submitted by Simons, Li & Associates, that the physical processes associated with sand and gravel mining and the impacts of sand and gravel mining on the streams, rivers and riverine structures are well understood. The concepts, theory and experience of the team have been incorporated in this report in the form of written material and mathematical models. In my opinion, excellent methods have been formulated and presented for evaluating both short-term and long-term response of sand and gravel mining on river behavior and associated river control structures - bridges and so forth.

Looking at current demands upon the sand and gravel industry, it is obvious that certain volumes of sand and gravel must be produced on an annual basis to meet current and future needs. A most important issue is the identification of guidelines from which regulatory statutes can be formulated. The needs of the sand and gravel industry, as well as the needs for their product, must be evaluated, formulated and integrated into any final regulatory procedure that is adopted by the State of Arizona.

It does appear that if regulatory procedures are to be developed and followed that a monitoring plan must be adopted and

implemented that will require monitoring of the removal of sand and gravel. From these data, responses of the system can also be documented and utilized to identify the volume of sand and gravel mining that can be mined from various reaches of the river systems. It may be essential to develop a red-line concept below which mining is not allowed to proceed. However, it is emphasized that if such a regulatory procedure is adopted, it must be recognized that rivers have a long memory and the regulatory body should not be surprised if there is additional degradation that will occur below the red-line simply because the river is slowly responding to past activities in the river. However, utilizing the red-line concept and limiting sand and gravel mining in the areas where there has been a drop below the red-line, the river will again develop a new bed profile at or above the hypothetical red-line. As materials accumulate above the red-line, mining may be initiated again under careful control and in accordance with regulatory statutes.

The most complicated aspect of the study deals with the formulation of legislative action that could be implemented to better control sand and gravel mining in the State of Arizona. As stated in the preceding paragraph, the processes and the impacts of sand and gravel mining on the environment and upon various related industries is well understood. Guidelines for better controlling sand and gravel mining can be formulated in the technical sense. The problem of refining the proposed methodologies for regulating sand and gravel mining and selling these concepts to the legislative bodies that must review and adopt such procedures is a much more difficult task. It does appear to be inevitable that some form of guidelines and regulatory laws will be passed to guide the future actions of the sand and gravel mining industry. In refining the materials presented by Simons, Li & Associates and in attempting to implement and adopt guidelines, it is suggested that the experienced engineers and the sand and gravel industry must work closely with those regulatory agencies if workable regulations are to be formulated and adopted to govern future sand and gravel mining in Arizona.

In conclusion, it has been a pleasure, as usual, working with Simons, Li & Associates, Inc., and I have appreciated the opportunity to interact with the highway staff and other participants in the task force and other bodies that have had a direct role in critiquing and helping to formulate this study.

Daryl B. Simons, Ph.D., P.E.
April, 1988

I. INTRODUCTION

Sand and gravel constitute one of the primary natural materials used in construction of the roads, bridges, and buildings required to support the needs of our society. The source of these materials, and the mining practices employed for harvesting them, can create problems for the very society that they serve. This is especially true in arid regions of the country where gravel mining operations are frequently located in the channel and overbank areas of floodplains historically known to be unstable during floods.

The alluvial river systems of the southwestern United States are typically ephemeral streams, flowing only in response to significant amounts of rainfall. As such, they are easily accessible and economical sources of sand and gravel. However, continual removal of these natural materials from a river system changes the hydraulic and sediment transport characteristics of the system. The river's response to such changes includes accelerated degradation, aggradation, headcutting and lateral migration. The occurrence of these phenomena can endanger adjacent property, highways, bridges, or other structures located in the floodplain environment.

The State of Arizona experienced several large floods during recent years. The presence of in-stream gravel pits fueled speculation that such operations contributed to river instability problems and may have been partly responsible for flood-related damage to roads/bridges and nearby riverbank property. The concern and speculation arising from this issue prompted the Arizona Department of Transportation to undertake this research project to study the problem, with the goals of developing technical procedures for analyzing the impacts of in-stream mining upon the river system, and of recommending legislative approaches to regulating the sand and gravel mining industry.

The study found that with the rapid population growth occurring in Arizona, the construction industry will place an even larger demand on the need for economical sources of sand and gravel materials. Development of aggregate resources will change the river environments, and planning for these changes will be essential in reducing the risk to river crossings, mitigating channel stability problems, and minimizing economic, social and environmental impacts, while at the same time providing needed aggregate products economically.

This study was structured to provide the basis for establishing prudent technical procedures and regulatory guidelines for in-stream sand and gravel extraction. The primary study objectives are summarized below. This final report is organized

to coincide with the logical progression of these study objectives.

- * Research laws and regulations used by other agencies, both within and outside of Arizona, to control in-stream sand and gravel mining. The objective of this review was to compare the status of in-stream mining regulation in Arizona to that in other states.
- * Research historical problems associated with in-stream mining. Case histories of existing gravel pits and bridge sites within the study reaches were compiled during this review. The purpose was to obtain a better understanding of the interaction of mining operations, bridge structures and channel behavior.
- * Investigate design criteria used by other agencies, both within and outside of Arizona, for the construction of bridge and highway projects within a river system influenced by sand and gravel extraction. A data set was compiled on the structural characteristics of bridges in the study reaches. This dataset was derived from as-built plans, inspection reports, and damage surveys.
- * Determine present and future regional demand for aggregate products within Arizona. The market potential and market value for sand and gravel products was assessed for the regional economy.
- * Establish a classification system for use in assessing, at a state-wide level, the river reaches which are currently, and will in the future, be resource areas for the sand and gravel mining industry. The classification system was structured to identify river reaches that have both acceptable quality and quantity of sand and gravel reserves, and identified incentives and constraints to the development of those reserves, including regional market potential, in-stream structures, and social/environmental conditions.
- * Formulate engineering parameters to provide a quantitative description of river characteristics. The engineering parameters required for the compilation of four data sets for each of the study reaches consisted of river topography, bed material gradation, hydrologic conditions, and mining activity. These data sets provided the factual basis for the development of technical procedures.

- * Develop technical procedures for quantifying river system impacts due to in-stream sand and gravel mining. Procedures were developed to assess both short-term and long-term impacts to the river stability. Emphasis was placed on developing procedures that are practical and easily implementable, while yielding prudent estimates of the response of a river channel to mining activity.
- * Determine the justification for the regulation of in-stream mining from both a technical and non-technical perspective.
- * As justified by the findings of previous study objectives, develop model legislation and guidelines for adoption by regulatory agencies.

II. REVIEW OF LEGISLATION & REGULATORY PRACTICES RELATED TO IN-STREAM MINING

2.1 Introduction

This review covers literature supplied by federal, state, and local agencies responsible for the regulation of sand and gravel mining operations. The bulk of the literature was gathered by Mr. Ottozawa Chatupron in the period from February and March of 1986 and has been supplemented by SLA staff during the course of preparation for this report.

The literature was divided into four categories: (1) federal programs, (2) California state programs, (3) state programs other than California, and (4) Arizona programs. A large amount of regulatory information is associated with the state of California, in conjunction with the Surface Mining and Regulation Act (SMARA). Policy guidelines have been established for in-stream sand and gravel mining operations as a result of the enactment of SMARA. Counties have primary jurisdiction over sand and gravel mining operations in California.

2.2 Federal Programs

2.2.1 General

A paper by Mossa (1983) provides an overview of the general regulatory environment for sand and gravel mining operators in the United States. At this time, there is no federal regulation of in-stream sand and gravel mining. Some federal laws could be interpreted as having an indirect affect on sand and gravel mining activities. These include the Rivers and Harbors Act of 1899 (Section 10), the Federal Water Pollution Control Act (FWPCA) Amendments of 1972 (Section 404), the National Environmental Policy Act, the Federal Land Policy and Management Act, and the National Flood Insurance Policy Act. Because federal law does not directly control in-stream mining operations, most of the responsibility is at the state and local government level. Local control takes the form of zoning ordinances, permits, plans, and variances. The focus of this regulation is primarily on operation and reclamation plans, not on planned resource development or environmental management. Mossa identifies the following issues related to in-stream sand and gravel mining:

- . A decrease in channel stability with regard to position and gradient
- . Impacts on flood rates and the flood boundary
- . Impact on water quality
- . Loss of floodplain habitat with impacts to fisheries and wildlife

The following general guidelines are put forth for in-stream sand and gravel development:

- . Avoid removal of riparian vegetation.
- . Excavation should not be permitted in channel bottoms or point bars.
- . Post mining landscape should be left in a stable, non-hazardous, and useful condition.
- . Encourage sand and gravel industry development in locations that will benefit (for example, where flood-control channelization is needed).

2.2.2 Corps of Engineers Policies and Guidelines

The Corps of Engineers (COE) studied sand and gravel mining operations in the Phoenix/Tempe area (Los Angeles District, 1981), and found that extensive mining is taking place. Most of the mining is not subject to floodplain regulations because state law exempts floodplain users prior to enactment. However, additions or changes are subject to regulation. COE also noted that multi-jurisdictional responsibilities hinder enforcement of existing regulations. They propose minimum guidelines for sand and gravel operations based on a report by Boyle Engineering (1980) (see discussion in Section 7.5.2). Defining the problem in the Phoenix metropolitan area, the COE notes that sand and gravel operations have followed the pattern of expanding urbanization. Streambed lands are under both public and private ownership. There is fragmented jurisdictional authority with involvement on the part of separate governments representing the Indian reservation, Maricopa County, and municipalities. Federal laws are not applicable to Indian reservations, but are followed on federal lands, or when federal grant monies to Indian tribes are involved. Maricopa County administers all unincorporated areas, and the municipalities administer within their corporate boundaries.

The current pattern of excavation is essentially random and has taken place in a leapfrog fashion. The COE estimated that planned excavation of the Salt River floodway could provide improved flood control. They recommend a channel excavated at a grade of 0.10% (approximately half the existing gradient), with 3:1 side-slopes to a depth of 30 to 40 feet below the floodplain. Maintenance of the channel grade will require grade control. Five structures are proposed: Central Avenue, 16th Avenue, 24th Street, I-10, and Scottsdale Road.

The Federal Water Pollution Control Act, Section 404 is administered by the Corps of Engineers. Barnett (1982) reviews the legislative history and the Corps administration of the permit process as it relates to the arid west. Barnett reviews the legislative history of Section 404, addressing the legislative intent related to several key issues in the Act. The 1972 amendments to the FWPCA adopted a broad definition of navigable waters, as follows: "waters of the United States, including the territorial seas". Barnett states that the 1972

legislative history shows that Section 404 was created to protect the Corps of Engineers and private dredging operations from the more comprehensive water quality program (Section 402). Section 404 was intended to put pressure on the Corps to end the practice when alternatives to open water disposal were available. Barnett quotes Senator Muskie as saying that the use of the word "fill" was to make clear that if the specific disposal site agreed upon by the Corps and the Environmental Protection Agency (EPA) was on land in the form of a fill, that there would be no ambiguity on the question of whether or not it also was covered by Section 404. Implementation of Section 404 by the Corps required substantial clarification of the term "navigable water". The Corps initially published regulations in 1974 that limited the scope of jurisdiction to "traditional" navigable waters. After a great deal of public controversy and congressional review, interim final regulations were published in July 1975 based on the expanded definition of navigable waters. The 1977 regulation threw out the term "navigable waters" altogether in favor of exclusive reference to "waters of the United States" for jurisdictional purposes. The Corps implemented the concept of a nationwide permit at this time that permitted, by regulation, many routine activities not specifically exempted by definition. Exempted activities included agriculture, silviculture, and construction.

According to Barnett, the 1977 Amendments to the FWPCA did not change the broad definition of navigable waters for the purpose of water quality, but did make the following key changes: 1) the ability to issue general permits; 2) exemption for routine activities considered to be of insignificant impact; 3) exemption from regulation any discharge of dredged material which is determined to be a "best management practice" under an approved Section 208 plan; 4) procedures for the states to assume administration of the Section 404 program; 5) procedures to expedite permit processing; 6) exemption of Federal projects if the impacts were addressed in an EIS submitted to Congress prior to authorization; 7) procedures for handling violations; and 8) recognition of the state's authority to control discharges of dredged or fill material within its jurisdiction (including the activity of any Federal agency).

According to Barnett, the Corps revised their regulations in September 1980; the regulations were not promulgated by the Reagan administration. The Reagan administration felt that the Section 404 program had gone far beyond its originally intended scope. The Reagan administration issued their revised regulations in July 1982. The Presidential Task Force on Regulatory Relief directed EPA to revise its regulations under Section 404(g)-(1) to provide increased incentives and simplified procedures for state assumption of the 404 program.

Barnett states that the debate over the appropriateness of the current section of 404 program has focused on four major issues. Those issues involve: 1) whether the program, as administered, is clearly what Congress intended; 2) whether administrative authority for the program should be with the Federal government, or delegated to the individual states; 3) whether the program represents Federal interference with state water allocations; and 4) whether the benefits derived from the program are worth the cost.

2.2.3 Federal Emergency Management Agency Policies and Guidelines

In their guidelines (1985), the Federal Emergency Management Agency (FEMA) does not specifically establish standards for sand and gravel mining within designated flood-hazard areas. The National Flood Insurance Program does require a floodplain-development permit. The standard for a floodplain-development permit prohibits development that will increase flood heights. A new sand and gravel operation would have to show that their operation would not have any significant adverse impact on flood elevations. If sand and gravel operations cause an alteration in a watercourse, modify the base (100-year) flood elevation, or alter the designated floodway, approval of any revision is required from FEMA. Revisions are in the form of either a Physical Map Revision (where selected map panels of the FHBW or the FIRM are modified to show the change), or a Letter of Map Revision (LOMR), which describes the changes made and officially states that corrections to maps have been accepted by FEMA.

2.3 Regulation in California

The State of California has passed a fairly comprehensive piece of legislation that regulates surface mining (1979). The Surface Mining and Regulatory Act of 1975 (SMARA) is administered by the Department of Conservation, Division of Mines, and the Geology Reclamation Board. The actual implementation of the act is a function of individual city or county governments in which the mining operations are located. The Reclamation Board reviews local actions and can intervene if they feel the act is not being enforced. The act set standards for mining practice and reclamation. The act also seeks to classify mineral lands, and provides guidelines for mineral-resource management.

The Reclamation Board has a special policy for sand and gravel operations in floodways. The Board found that sand and gravel extraction near a levee can be detrimental to the integrity of the levee and/or can result in channel changes. The need to clear riparian vegetation during mining was found to be detrimental to flood management and wildlife habitat. Permit approval by the Reclamation Board is required before mining is allowed in a designated floodway. The following requirements must be met in order to obtain a permit.

General Requirements:

1. Excavated material cannot be stockpiled within the limits of the designated floodway during the flood season.
2. Debris has to be completely cleared from the floodway.
3. Damage to levees or access ramps must be promptly repaired.
4. Excavation will not take place within 100 feet of the edge of a streambank.
5. Replanting of specified vegetation.
6. Extraction operations will not entrap fish or cause siltation of spawning gravels.

Specific Requirements:

1. Excavation will not take place within 100 feet of the toe of a levee, toe of a streambank, or an adjacent property line.
2. Side-slopes less than 3:1 (5:1 if excavation by dredge).
3. Excavation depth no lower than bottom of the low-water channel of the streambank adjacent to the excavation area (or not to exceed approved limit for excavation by dredge).
4. Uniform bottom excavation and, if in the floodway, clear and uniform excavation prior to flood season.

Examples of county implementation of SMARA associated with sand and gravel regulation are given by Orange County (1986, undated), Sonoma County (1978), Riverside County (Edwards, 1986), and Sacramento County (Aggregate Resource Management Technical Advisory Committee, 1974). Orange County has both zoning and mining regulations. The zoning ordinance (1986) is administered by the county Environmental Management Agency, and has the following requirements:

- . Limits pit depth to 150 feet from existing grade
- . Requires reclamation of mined areas
- . Requires a drainage and erosion-control plan
- . Requires a plan of operations, including depth of all proposed excavation

The county ordinance (undated) requires that all sand and gravel operations have a permit obtained from the county Department of Building and Safety. Standards are provided for inactive and active (or planned) operations. The following requirements are of interest:

- . Setbacks - 50 feet, or as determined by the administrator based on the preservation of an adjacent flood-control channel.

- . Slopes - inactive, 1.5:1
Active, if seepage problems exist (i.e., the pit is below the existing water table) a perimeter slope of 2.5:1, if not, then 1.5:1. In addressing more complex problems, Orange County contracted for detailed studies to assess the impacts of sand and gravel operations at the basin level. A study of San Juan Creek and Trabuco Creek in Orange County (SLA, 1984) was conducted to assess aggradation/degradation along river reaches in the basin. The study applied hydrologic, geologic, geomorphic, hydraulic and sediment transport analysis.

Methodologies used included:

- . Hydrologic - at-gage statistical analysis (Log-Pearson III and Pearson III), and watershed modeling using programs HEC-1 and SWMM
- . Geomorphic analysis - detailed geologic description of the basin, description of channel reaches, bank-erosion history, aggradation/degradation history, evaluation of man's activity
- . Hydraulic - water-surface profile determination using program HEC-2
- . Watershed sediment yield - use of programs MUSLE and PSIAC
- . Sedimentation - estimation of bed material transport, coarse-sediment yield, estimation of the dominant discharge, incipient-motion analysis (static equilibrium), equilibrium-slope analysis (dynamic equilibrium), and local scour at bridges
- . Sediment transport - use of QUASED model, transport by size fractions, and determination of bed armoring.

The Sonoma County ordinance (1978) regulates surface mining and was adopted June 1978. The following standards in Section 26A-6 pertain to gravel-mining operations:

- . In-stream operations - required to avoid modification of the hydraulic capacity of the channel that would cause upstream or downstream erosion, or that would modify the streamflow (magnitude or direction) that would cause upstream or downstream erosion.
- . Setbacks - 25-feet to property lines or public streets; may be required to submit a geotechnical report investigating the stability of excavation and the effect on adjacent property.

Substantial litigation over the effects of in-stream sand and gravel mining on river stability occurred in Sonoma County in the late 1970s. Newspaper articles (Healdsburg Tribune, 1980) describe the outcome of this litigation and proposals for more restrictive regulation of sand and gravel operators. The litigation between sand and gravel companies and adjacent

property owners along the Russian River and Dry Creek was settled out-of-court. The total settlement was \$705,000. The proposed aggregate-resource management plan would curtail sand and gravel operations in in-stream and floodplain-terrace locations. Farmers and property owners were in favor of the plan. Gravel miners were opposed, saying the plan would result in unacceptable economic impacts.

One of the reports produced on the above litigation was by Slosson and Associates (1980), which evaluated the impact of in-stream and terrace sand and gravel mining operations on bed and bank stability of the middle reach of the Russian River and Dry Creek in Sonoma County, California. The report presents data on gravel extractions volumes, topographic data (field surveys, including measured cross-sections and river profiles), aerial photos (1940-1979), field investigations (soil types, existing erosion-control measures, types of riparian vegetation, locations of rock outcropping, and man-made structures such as dams and levees), existing reports and publications, and documentation of meetings with local, state, and federal agencies. The study concludes, based on a sediment bed-material mass balance, that sand and gravel extraction has caused a significant deficit in the sediment balance, resulting in property damage in these river reaches. Slosson estimated a replenishment rate of 0.27 Mtons/year. Another estimate of the replenishment rate was given in a report by D.B. Simons of 1.0 Mtons/year. Slosson considered their estimate more reliable than Simons, since it was based largely on actual measurements. However, Slosson does not include any estimate of the measurement error for this data. It is interesting to note that a measurement error of -25% for sand and gravel extraction and +25% for streambed volume change greatly reduces the difference between the two estimates. This error would revise estimated recharge based on a sediment balance to .71 Mtons/year. An error of ± 25 percent is typical of many fluvial measurements, and bias in selection of river cross-section locations.

Riverside County has addressed regulation of gravel mining on a pit-by-pit basis. Information on Riverside County's regulatory program was provided by the Chief Engineer for the Flood Control and Water Conservation District, Kenneth Edwards (1986). An example of the type of review given a large gravel-mining operation is given in intergovernmental correspondence regarding an operation on the San Geronio River located just south and west of I-10. Edwards stated the issues related to granting a permit for this operation in a letter to Carolyn Luna of the Riverside County Planning Department as: 1) the existing levee cannot be assumed to be sufficient to prevent the river from flowing into the proposed pits, the resulting erosion could undermine upstream railroad and highway bridges (it was assumed that headcutting erosion would occur at a grade twice that of the existing natural channel); 2) that pipelines are at risk due to

potential headcutting; and 3) mining operations had caused local drainage problems. A letter from Norman Arno, Chief Engineer LACOE, stated the following COE guidelines: 1) on the excavated landward side of a levee, the excavation should not extend below a plane passing through the present ground surface at a point 60-feet from the levee, and dropping at a ten percent slope; 2) on the floodway side of a levee, the excavation should not extend below a plane passing through the present ground surface at a point 200-feet from the levee and dropping at a slope of five percent, excavation should be made with a length to width ratio of about five (downstream length to cross channel width); and 3) headcutting is assumed to start at half the depth of excavation and to proceed upstream at twice the slope of the existing natural ground. Riverside County implemented SMARA with Ordinance No. 555, which requires the operator to submit mining and reclamation plans. Public hearings are held prior to granting a permit. Edwards, in a letter to the County Planning Director, Patricia Nemeth, proposed revisions to Ordinance No. 555 to incorporate COE guidelines and to restrict operations in the floodway that might increase flood damage.

Sacramento County conducted an aggregate resource study (Aggregate Resource Management Technical Advisory Committee, 1974) that estimated sand and gravel demand based on population growth and per capita consumption. The study reviewed standard specifications for aggregate products, noting that emphasis on good quality products from the construction industry has increased in recent years. The potential locations and geologic sources of aggregate materials is presented. Areas where land-use conflicts are likely are noted. An estimate is made of the number of square miles that will need to be set aside to meet aggregate resource demand for 25 years. Areas were identified within the county that can be set aside for this land use without conflict. Land-use management is determined to be the best alternative for meeting aggregate resource demand and avoiding adverse impacts to adjacent land uses. Regulations were proposed that would require: 1) a mining plan, 2) a reclamation plan, and 3) property-line setbacks. Regarding runoff and flood control, proposed regulation would require that mining operations complement the design and purpose of drainage-basin flood-control systems and local drainage improvements. Approval from the Sacramento Division of Water Resources would be required prior to issuance of a permit.

Ventura County (1985) has adopted a resolution establishing a "red-line" profile and width policy for mining and excavation in the Santa Clara River. The policy is comparatively simple and consists of the following requirements:

1. In-river mining will be considered on the basis of a river management strategy which generally limits mining

to the aggradational reaches of the river, with the constraint of protecting structures.

2. Excavation will be limited to the red-line profile and width standards, as determined by the Flood Control District, and be defined by a table of horizontal and vertical control data and excavation widths which have been plotted on drawings on file with the Public Works Agency.

The "red-line" boundaries were defined by a comprehensive engineering analysis of the Santa Clara River. Amendments to the "red-line" boundaries are possible, provided stabilization measurements for the vertical and lateral adjustment of the river are introduced. Adoption of the "red-line" boundary gives a common reference for all users of the river environment. In addition, since the boundaries are defined through a cumulative analysis of the river system both with and without gravel mining, the effect of joint operation of several sand and gravel mines on the river can be assessed.

In California, sand and gravel operations have also been subject to water-quality monitoring and waste-discharge requirements, as implemented by the California Water Quality Board. Issues identified (Luke and Salisbury, 1974) are related to impacts on in-stream biota from sediment deposition or turbidity, reduced ground-water recharge due to sealing of recharge areas by fine sediments, and increased flood potential from sand and gravel operations in the floodway. Water quality permits issued in the San Diego Region (1983, 1978) provide limits on the amount of sand and gravel that can be extracted, and set waste water discharge requirements for settling ponds. The California Division of Mines and Geology works with the various Regional Water Quality Boards to meet water-quality standards, as legislated by the Porter-Cologne Water Quality Control Act, as these relate to mining operations (California Division of Mines and Geology, 1973).

2.4 Regulation in Other States

Several other states, each with a significant coal-mining industry, have adopted legislation for regulation of surface mining. This allows these states to administer parts of the federal program rules implementing the Surface Coal Mining and Reclamation Act. While the federal legislation pertains to coal mining only, state laws tend to regulate all surface-mining activities, which includes sand and gravel extraction. Montana and Colorado's programs are examples of state-level regulation of surface mining. Montana's regulations (Department of State Lands, 1980) require that a detailed permit application be submitted that includes a map of intended operations, a detailed

reclamation plan, and a bond of at least \$200 per acre. The emphasis in Montana's program is reclamation; no analysis of the impacts of gravel mining on river stability is required or implied. Colorado (Mined Land Reclamation Division, 1978) requires a surface-mining operation to submit a detailed permit application with information on mining plans, reclamation plans, base-line data (water, wildlife, soils, vegetation, and climate), an estimate of reclamation costs, and various legal information (right of entry, property description). Colorado regulations do not specifically address in-stream sand and gravel mining.

States with significant aquatic habitat and/or in-stream recreational resources have adopted regulations on sand and gravel mining to protect those resources. Washington, Oregon, and Idaho have each adopted this type of regulation. Washington's aquatic land management plan (Department of Natural Resources, undated) has a river-management component. The parts pertaining to sand and gravel mining include: 1) protection of braided and meandering channels from mining activity; 2) river channel relocation is permitted only when overriding public benefit can be shown; 3) sand and gravel removals are not permitted beyond the perimeter of navigable rivers, except as authorized under a department of fisheries and game hydraulics permit; 4) sand and gravel removal beyond the wetted perimeter of a navigable river is considered under the following conditions: 1) no alternative upland source is available, b) pit configuration is designed to create improved river floodplain features, c) recreation benefits are provided, d) would reduce sediment deposition in downstream rivers and lakes, and e) would reduce damage to private or public land; and 5) sand and gravel removal beyond the wetted perimeter of a navigable river is not considered under the following conditions: a) below a dam, b) from detached bars and islands, c) if unstable hydraulic conditions will be created, d) if impacts to the esthetics of nearby recreation facilities will occur, and e) if negative water quality will result. Washington's general policy statement for sand and gravel extraction (Department of Natural Resources, 1984) states that upland deposits of sand and gravel are non-renewable and have become less available. The industry is relying more on renewable river gravels than upland deposits. The use of river gravels can cause aquatic habitat damage to fishery and spawning areas and to gravel bars that provide access for various aquatic-land recreational users. The policy is therefore, to allow sand and gravel extraction on aquatic lands, but only when a more preferable upland site is unavailable.

Oregon garners a royalty on sand and gravel extraction (Division of State Lands, undated). The rules for this tax provide uniform methods with which to measure and verify the quantity of material extracted. River beds are owned and controlled by the state. The regulations do not control operational or reclamation aspects of sand and gravel mining.

The lessee is required to file a plan that gives a general volume and rate of extraction for the duration of the lease. A report by the Oregon Water Resources Research Institute (Klingeman, 1979) studied gravel mining practices on the Willamette River and outlined a comprehensive research plan addressing various issues. The report finds that sand and gravel mining is an important industry, but that the lack of quantitative information on sediment transport and erosion processes raise issues of stream-bank stability and potential impacts on recreational usage and fisheries. The objective of the study was to understand the sediment transport regime of the Willamette River, prioritize this information for decision making, and demonstrate how decisions can be made based on this information. Typical gravel mining techniques in Oregon are bar-scalping to the depth of the water surface, or mining in the floodplain to a depth equal to the water level in an adjacent water course. The study proposes a comprehensive attack on the problem, beginning with a thorough understanding of sediment budget and sediment transport rates, and development of river-management tools.

Idaho regulates the removal of sand and gravel below the mean highwater mark (Department of Water Resources, 1985). The Department of Water Resources (DWR) requires the following construction procedures: 1) no construction equipment below the existing water-surface elevation without prior approval; 2) temporary structures should be designed to handle anticipated high flows during construction; 3) only the minimum necessary disturbance to the natural appearance; 4) fill material must be placed in horizontal lifts; and 5) DWR can limit the period of construction to minimize conflicts with fish spawning, migration, or with recreational use.

Contact with the Nevada Department of Transportation (NDOT) and the Nevada Legislative Council Bureau indicated there were no existing statutes regulating in-stream sand and gravel mining. With the exception of an isolated site on the Carson River, NDOT was not aware of any in-stream mining operations within Nevada. At the present time, all sand and gravel extraction is taking place on alluvial fans. The absence of in-stream mining problems in Nevada is, no doubt, largely due to the fact that the two major metropolitan areas (Las Vegas and Reno) are not situated adjacent to major ephemeral rivers as are Phoenix and Tucson.

The New Mexico Department of Transportation (NMDOT) has also experienced very few problems with in-stream sand and gravel mining. As with Nevada, most of the sand and gravel operations in New Mexico are located on alluvial fans, rather than in river floodplains. NMDOT indicated there was no existing or pending legislation which would specifically regulate in-stream sand and gravel operations.

2.5 Regulation in Arizona

Arizona law relative to floodplain management was reviewed. Title 48, Section 3609 of the Arizona Revised Statutes mandates that the board of directors of a flood control district shall adopt and enforce regulations governing floodplains and floodplain management in its area of jurisdiction. This shall include regulations for all development of land; construction of residential, commercial or industrial structures; or a use of any kind which may divert, retard or obstruct floodwater and threaten public health or safety, or the general welfare. The regulations shall also establish minimum flood damage prevention requirements for land uses, structures, and facilities which are vulnerable to flood damage. The regulations shall be in compliance with state and local land-use plans and ordinances, if any.

The law does provide for variances from the regulations that do not result in danger or damage to persons or property in floodplains in the area of jurisdiction. Unless expressly provided, the adopted regulations will not affect existing legal uses of property or the right to continuation of such legal use. However, if a nonconforming use of land or a building or structure is discontinued for twelve months, or destroyed to the extent of 50% of its value, any further use shall comply with the regulations adopted by the district.

ARS Title 48, Section 3610 enables the governing body of an incorporated city or town to assume the responsibility for floodplain management. If the city or town declares by resolution that it no longer wishes to assume the floodplain management and regulation function, then these functions shall be the responsibility of the flood control district.

In general, the regulation of sand and gravel operations in association with floodplain management is based on ARS 48-3613 which addresses the authorization required for construction in watercourses. The law provides that sand and gravel operations which will divert, retard, or obstruct the flow of waters in a watercourse must comply with adopted regulations governing floodplains and floodplain management and that operators shall secure written authorization from the board of the district in which the watercourse is located.

ARS Title 11, Section 251 allows the board of supervisors of a county to adopt and enforce standards for excavation, landfill and grading to prevent unnecessary loss from erosion, flooding and landslides subject to the prohibitions, restrictions and limitations as set forth in ARS 11-830. ARS Title 11, Section 830 addresses restrictions on regulation through zoning ordinances. The law provides that nothing contained in any zoning ordinance shall prevent, restrict or otherwise regulate the use or occupation of land or improvements for "mining

purposes", if the tract concerned is five or more contiguous commercial acres. A current court case examines the issue of whether the in-stream sand and gravel mining operation larger than five contiguous acres is exempt from zoning ordinance requirements.

Floodplain regulations for Yuma County, Pima County, the Flood Control District of Maricopa County, the City of Phoenix, and the City of Mesa were reviewed. To obtain a floodplain use permit in Yuma County (Public Works Department, 1984) the sand and gravel operator must submit a permit application containing the following information: 1) excavation limits, location of stock piles, and pit depth; 2) phasing and method of operation; and 3) description of proposed watercourse alterations. The operation is not permitted to store materials within the floodway, nor is the storage of buoyant, flammable, explosive, or injurious materials allowed in areas subjected to flooding.

Pima County (Department of Transportation & Flood Control District, 1985) requires that the sand and gravel operator submit a permit application containing a development plan, a reclamation plan, and assurance for reclamation costs. The development plan requires analyses of hydrologic, hydraulic, and sediment transport issues. The scope of work for the sediment transport analysis is determined on a case-by-case basis. The development plan must show set-back distances, location of structures and equipment, and the phasing of operations. The reclamation plan requires that post excavation slopes be stable and that set-back distances from property lines be established.

The Flood Control District of Maricopa County (1986) excludes certain types of sand and gravel activity from the floodplain. The regulations also require a development plan and a reclamation plan. Guidelines are given in addition to the regulations to assist the sand and gravel operator in preparing a permit application. The exclusions prevent permitting if the sand and gravel operation would be a hazard to life, property, the watercourse, or crossings (i.e., bridges or utility crossings). For sand and gravel operations within the designated floodway, the development plan may require a sediment transport analysis. The reclamation plan addresses the stability of the post-mining floodway. Guidelines help the applicant to identify operation and reclamation issues pertinent to the operation. These guidelines include questions relating to whether the operation is: 1) in the floodway or floodplain; 2) likely to affect channel form; 3) close to property or channel crossings; and 4) in a channel that is known to aggrade or degrade, or in a zone of channel headcutting.

The City of Phoenix ordinance (Floodplain Board, 1981) allows sand and gravel mining within the floodway provided that excavations do not present a hazard to other development and

river crossings. The ordinance excludes stockpiling within the designated floodway but permits it within the floodplain.

The City of Mesa ordinance allows gravel mining if the property is zoned for such use. Individual sand and gravel mining operations are subject to stipulations on a case by case basis. An example of such stipulations is the Shill-Biggs zoning case, for a gravel pit on the west side of Mesa Drive, north of Lehi Road. In this case, dikes or levees were not permitted and the excavation depth was limited to 100 feet below natural ground (with 1:1 side-slopes). The direction of excavation was specified as south to north with provisions to carry local runoff around the pit to the river. A requirement was also imposed that the pit be backfilled upon completing sand and gravel extraction.

An industry perspective on the political issues faced by sand and gravel operators was given by the magazine Southwest Contractor, in an August 1985 article entitled "River of Controversy" (1985). The issues discussed relate to sand and gravel mining on the Salt River, and included development of Rio Salado, flooding and flood control, and ownership of river bottom property. The article points out that sand and gravel is a significant but finite resource. The Rio Salado project is considered the number one problem facing sand and gravel operators on the Salt River. The rock producers feel that the project, as proposed, has not properly taken into account their interests. The condemnation of private property owned by mining companies for this project is strongly questioned. Private development of previously mined land has been undertaken by several companies (CALMAT and Tanner). As an alternative to Rio Salado, the rock producers propose channelization of the Salt River with the excavation conducted by the producers. The project would be engineered by the Flood Control District of Maricopa County. The period of construction is estimated at five to eight years.

III. STRUCTURE HAZARD

Arizona is crisscrossed by comprehensive networks of transportation and transmission routes. Transportation facilities include: rail, highway, and air routes; and transmission facilities include: water (domestic and irrigation), gas, electrical and communication lines. These routes interconnect Arizona cities and connect Arizona to the nation as a whole. Crossings of natural and manmade waterways are a frequent occurrence and are at significant risk from potential floods. All of these routes (including air) have been interrupted by periods of severe flooding. Damage to these systems is a significant cost in itself, but the interruption of the service they provide is often far more costly both to the economy and to public safety and welfare.

A general accounting of flood damage to all transportation and transmission routes is not the focus of this study. Of primary interest are the damages that have occurred to the highway system. Highway bridges are probably the most numerous river-crossing structures, and can be assumed to characterize many of the problems of other river-crossing structures in a river reach. Highway-bridge crossings are constructed and maintained by state, county, and local highway departments. The maintenance of these bridges requires periodic inspections, the majority of which are carried out by ADOT bridge inspection staff. All counties in the state with the exception of Maricopa have ADOT conduct this inspection. The computer database maintained by ADOT contains information on the majority of bridges in the state (this may exclude bridges on private land, military bases, forest service roads, and national parks, however).

Data on damage to highway bridge structures was compiled from Flood Damage Reports and Federal/State Damage Survey Reports. Additional data on specific projects that ADOT has conducted on an emergency basis have been compiled from the database for use with this study. Emergency replacement (ER) project funds have been made available to ADOT after disastrous floods. To date, all ER projects in Arizona are associated with flood damage to bridge structures. ADOT also maintains documentation on repair cost associated with scour damage to bridge structures for non-disaster related conditions. This documentation is compiled on an informal basis by ADOT's scour team.

3.1 Existing Bridge Structures Crossing Waterways

ADOT's inventory of Arizona bridges lists 1,514 structures over waterways. ADOT also inspects 95 county bridges and 606 city bridges that are over waterways. Table 3.1 gives a breakdown by county and city of bridge structures over waterways.

TABLE 3.1. Bridge Structure Over Waterways (Source: Arizona Bridge Inventory)			
County/City	ADOT Bridges	County Bridges	City Bridges
Apache	40	18	
Eager			1
Springerville			1
Cochise	67	108	
Bisbee			4
Sierra Vista			12
Coconino	127	28	
Flagstaff			21
Williams			6
Gila	28	7	
Globe			12
Hayden			1
Miami			7
Payson			1
Graham	2	23	
Safford			4
Greenlee	2	15	
Clifton			6
La Paz	23	2	
Maricopa	599	194	
Avondale			1
Buckeye			1
Chandler			2
Gila Bend			1
Gilbert			6
Glendale			11
Goodyear			1
Mesa			51
Paradise Valley			2
Peoria			2
Phoenix			138
Scottsdale			90
Tempe			19
Mohave	65	5	
Kingman			7
Lake Havasu City			1
Navajo	51	21	
Winslow			7
Pima	296	197	
Tucson			143
Pinal	53	74	
Superior			1
Santa Cruz	23	17	
Nogales			11
Yavapai	77	86	
Clarkdale			3
Cottonwood			3
Prescott			23
Yuma	61	100	
Yuma			6

Approximately 80 percent of these structures are less than 100 feet in length and typically span irrigation canals and small washes. Ten percent of structures spanning waterways are 100 to 200 feet in length, and five percent are 200 to 400 feet in length. Structures over 800 feet in length constitute about one percent of all bridge structures over waterways in Arizona.

3.2 Flood Damage to Existing Bridge Structures

Table 3.2 summarizes the frequency and cost of emergency repair and scour repair projects in Arizona. Table 3.3 summarizes flood-damage estimates to transportation systems as reported from COE flood damage reports.

3.3 Transportation Planning

Arizona's highway system has been expanding to keep pace with population growth. In the future, sustained population growth is expected in all areas of the state. The state's highway network will also expand adding road mileage, much of which will occur in metropolitan areas. Three out of four new people moving to Arizona between now and the year 2000 are expected to live in the Phoenix and Tucson metropolitan areas. This will necessitate the early construction of expanded regional transportation systems for these areas. In addition, many of Arizona's mid-sized urban areas and rural towns are facing growth prospects at least as dynamic as the major metropolitan areas. Without the construction of new roads and the reconstruction and widening of existing roads to higher standards, the cost of congestion will be staggering.

In fiscal year 1986, ADOT invested \$370.9 million dollars maintaining and improving the state highway system. Over the next five years, ADOT will invest more than \$2.6 billion dollars on the highway system. Table 3.4 identifies the capital investment by counties.

TABLE 3.2. Summary of Emergency Repair Projects
(Source: ADOT Project Expenditures)

Region	River	Reach	Number of Projects	Amount
Basin & Range	Gila	Confluence-Painted Rock	0	NA
		Painted Rock-Salt River	0	NA
		Salt River-Coolidge	14	\$ 6,382,556.73
		Coolidge-Safford	5	1,192,334.28
		Safford-headwaters	1	92,637.17
		Hassayampa	2	634,407.85
		Agua Fria	7	5,813,390.29
		New River	4	18,192.76
	Salt	Confluence-Granite Reef	13	26,262,560.62
	Santa Cruz	Confluence-Tucson	4	495,194.06
		Rillito/Pantano	12	683,878.17
		Tucson-Nogales	15	6,445,537.53
	San Pedro		2	112,764.29
	Bill Williams	Confluence-Alamo Lake	0	NA
		Alamo Lake-headwaters	0	NA
	Colorado	Border-Imperial	0	NA
		Imperial-Parker	0	NA
		Parker-Davis	0	NA
		Davis-Hoover	0	NA
		Hoover-Glen Canyon	0	NA
Central Highland	Verde	Confluence-Bartlett	0	NA
		Horseshoe-Camp Verde	1	290,095.97
		Camp Verde-headwaters	0	NA
	Upper Salt	Roosevelt-headwaters	0	NA
Colorado Plateau	Little Colorado	Confluence-Winslow	0	NA
		Winslow-Holbrook	0	NA
		Holbrook-headwaters	0	NA
	Puerco		0	NA

TABLE 3.3. Summary of Flood Damages to Transportation Systems

RIVER	1/ Dec 1965 Jan 1966	2/ Oct 1972	3/ Oct 1977	4/ Feb-Mar 1978	5/ Dec 1978	6/ Feb 1980	7/ Oct 1983
Salt River Granite Reef Dam to Gila River	\$1,686,000						
Gila River to Gillespie Dam	91,000						
Gila River Safford Valley, Graham County		227,000					
Gila River in Duncan & York Val- leys, Greenlee Cty		1,000					
San Francisco River at Clifton		184,000					
Hogales Wash Santa Cruz County			69,000				
Santa Cruz River, Santa Cruz County			682,000				
Santa Cruz River, Pima County			784,000				
Santa Cruz River, Pinal County			54,000				
Salt River from Granite Reef Dam to 115th Avenue				11,809,000			
Gila River Maricopa County				340,000			
Salt River, Metro Phoenix					17,985,000	16,339,000	
Gila River, Metro Phoenix					1,526,000	1,360,000	
Agua Fria River, Metro Phoenix					1,999,000	4,242,000	
All rivers within Pima County							28,000,000
All rivers within Greenlee County							4,320,000
All rivers within Santa Cruz County							3,879,586
All rivers within Graham County							1,660,000

REFERENCES FOR TABLE 3.3

- 1/ Flood Damage Report on Flood of December 1965-January 1966
Salt and Gila Rivers, Granite Reef Dam to Gillespie
Dam, Arizona U.S. Army Corps of Engineers, April 1966.
- 2/ Flood Damage Report, Flood of October 1972
Gila River Basin above San Carlos Reservoir, Arizona
and New Mexico, U.S. Army Corps of Engineers, August
1973.
- 3/ Flood Damage Report on Storm and Floods on 6-10 October 1977
Santa Cruz, Gila, and San Pedro Rivers, Arizona
U.S. Army Corps of Engineers, September 1978.
- 4/ Flood Damage Report, 28 February ~ 6 March 1978
On the Storm and Floods in Maricopa County, Arizona
U.S. Army Corps of Engineers, February 1979.
- 5/ Flood Damage Report, Phoenix Metropolitan Area, December 1978
Flood, U.S. Army Corps of Engineers, November 1979.
- 6/ Phoenix Flood Damage Survey, February 1980
U.S. Army Corps of Engineers, April 1981
- 7/ Federal/State Damage Survey Reports, October 1983
Federal Disaster Declaration
Arizona Division of Emergency Services

TABLE 3.4		
Planned Road & Bridge Construction by ADOT Fiscal Year 86-87 Through Fiscal Year 90-91 (Source: Five-Year Transportation Facilities Construction Program, ADOT)		
<u>County</u>	<u>Projected Construction Funds</u>	
Maricopa	\$	2,032,415,000
Pima		183,320,000
Coconino		119,510,000
Gila		80,590,000
Mohave		51,190,000
Navajo		49,970,000
Yavapai		39,910,000
Pinal		31,985,000
La Paz		28,946,000
Yuma		20,220,000
Apache		14,880,000
Cochise		14,585,000
Santa Cruz		6,720,000
Graham		2,750,000
Greenlee		<u>1,040,000</u>
Total	\$	2,678,031,000

IV. ECONOMIC VALUE

Literature and data on the economic aspects of the sand and gravel industry was gathered and reviewed. Information was available from private and governmental sources. Basic data on resource areas in Arizona, annual production and value of rock products, and transportation costs were compiled from the literature. Sources of economic information included the Arizona Rock Products Association (1986), the Arizona Bureau of Geology and Mineral Technology (formerly the Arizona Bureau of Mines) (Keith, 1969; Williams, 1967), the U.S. Geological Survey (Moore and Varge, 1976), and the U.S. Army Corps of Engineers (Los Angeles District, 1981).

4.1 Resource Identification

Resource information was compiled from data obtained from the U.S. Bureau of Mines, Arizona Bureau of Geology and Mineral Technology (formerly the Arizona Bureau of Mines), and the Arizona Department of Transportation Material Section. The U.S. Bureau of Mines maintains working data files on sand and gravel operations as a part of the Minerals Availability System. The Bureau of Geology and Mineral Technology annually consolidates statewide sand and gravel production statistics from this database, and publishes this information as a part of the Department of the Interior Mineral Yearbook. From 1952 to 1975, the Mineral Yearbook published both state and county production statistics. Since 1975, only statewide statistics have been published.

Sand and gravel deposits derived from stream action occur in all counties of Arizona, but the quantity and quality vary greatly statewide because of different geologic, topographic and climatic conditions. Keith (1969) provides a general description of where sand and gravel deposits occur in the three physiographic regions of Arizona (see Figure 4.1). The geology of these three regions is complex and varied.

- * The Basin and Range region includes the deserts of southern and western Arizona; the Gila River and the Colorado River below Hoover Dam are the primary drainages. In the Basin and Range region, the best deposits of sand and gravel occur in alluvial fans along mountain ranges where intermittent streams constantly supply new deposits. Stream channels and dry washes yield a large part of the sand and gravel production.
- * The mountainous Central Highlands are drained by the upper tributaries of the Gila River; the Verde and the Salt Rivers. The mountain region has good quality, but generally small, alluvial deposits of sand and gravel along both the stream channels and the terraces along the valley sides.

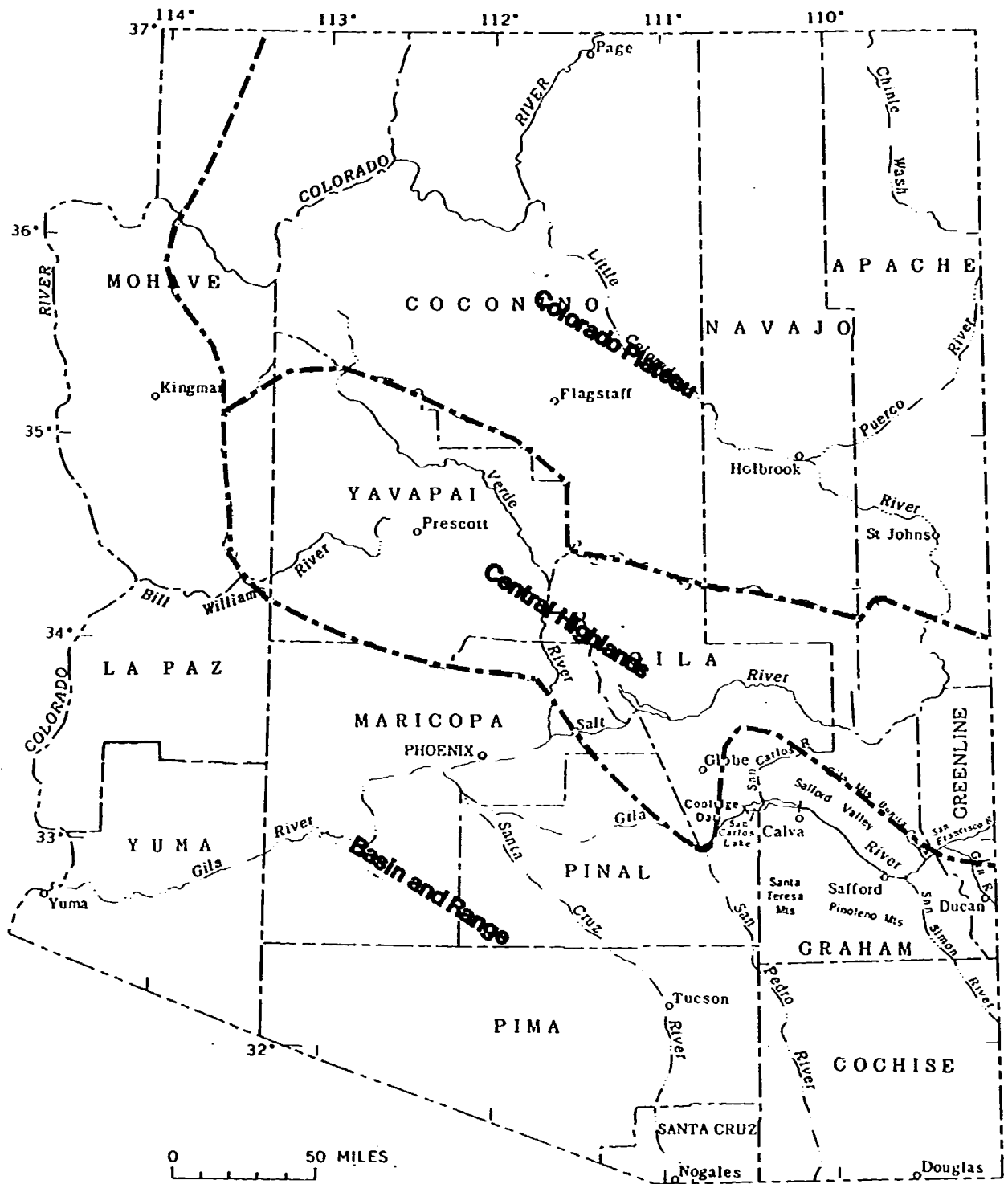


Figure 4.1. Physiographic Regions in Arizona
(Source: Keith, 1969)

- * The northern Colorado Plateau region is drained by the Colorado and Little Colorado Rivers. For the Plateau region, the best commercial deposits occur along the streams and washes in local bars and terraces, but they are rather thin and limited in area.

The distribution of sand and gravel in Arizona is the result of natural disintegration and abrasion of rock and the subsequent transport and deposition. The quality of a deposit depends on the parent rock constituents, the duration of weathering and erosion processes, and the transportation and deposition processes. Most rock formations yield sand and/or gravel, but the distribution of sizes and the particle shape can vary greatly. Table 4.1 gives a breakdown of sand and gravel quality by parent rock type. Table 4.2 shows the relationship of sand and gravel quality to transport mechanism. In Arizona, the most important deposits of sand and gravel are formed by stream action.

Stream action can lead to various types of deposits including: basin and valley fills; remnant and active stream channels; stream terraces; and alluvial fans. Overall, the quality of sand and gravel deposits occurring from stream action depends on parent-rock source and the deposition process.

TABLE 4.1. Sand and Gravel Quality by Parent Rock Type (Source: Keith, 1969)		
Parent Rock	Quality	Comment
Sandstone	Excellent	Both sand & gravel
Conglomerate	Excellent	Both sand & gravel
Friable sandstone	Excellent	Little or no gravel
Dune and beach sandstone	Excellent	With some beach gravel
Limestone & dolomite	Good	
Shale and Schist	Poor	
Granite and diabase	Good	
Basalt	Excellent	Aggregate sources
Gneiss	Good	Sand
Gneiss	Poor	Gravel

TABLE 4.2. Sand and Gravel Quality by Transport Process
(Source: Keith, 1969)

Transport Process	Quality	Comment
In-place	Poor	Chemical alteration, poorly sorted sizes
Talus	Good	Poorly sorted gravel, little sand
Wind	Good	Sand only
Wave	Excellent	Sand, beach gravel
Stream	Excellent	Sand and gravel

Moore, et al (1976) compiled a map showing aggregate deposits in the Phoenix area. The map scale is 1:250,000 and shows construction material exposed at the ground surface. The map also shows the approximate location of sand and gravel pits, and rock quarries. The COE (Los Angeles District, 1981) estimates in-stream aggregate resources in the Phoenix area to be 368 million cubic yards (490 million tons) over a 33-mile long reach of the Salt River from Granite Reef dam to 67th Avenue. Through the main urban area of Phoenix and Tempe, in-stream aggregate resources are estimated at 120 million cubic yards (160 million tons) for this eleven-mile reach.

The Arizona Department of Transportation Materials Section has compiled inventories, by county, of borrow and aggregate sources from pits which they lease or own. Published inventories exist for twelve Arizona counties: Apache, Cochise, Coconino, Graham, Mohave, Maricopa, Navajo, Pima, Pinal, Santa Cruz, Yavapai, and Yuma. The inventories for Cochise, Graham, Pinal, Pima, Santa Cruz, and Yuma Counties were compiled in the 1960s, and therefore, cannot be considered as a reliable guide to ADOT activity at the present time. Extensive unpublished information is available from files of the Materials Section related to ADOT pits. Assistance was provided by the Materials Section in providing an up-to-date inventory of material pits.

An accurate assessment of sand and gravel resources for the physiographic regions of Arizona requires extensive field investigation. Such investigation has been conducted by the Materials Section of ADOT at over 7,000 pits located throughout the State. The majority of these investigations relate to borrow sources but some 1,000 pits, located in rivers and washes, have been sampled as aggregate sources. Extensive analysis is conducted by the Materials Section on the materials at each site, including tests of the gradation, swell potential, Atterburg limits, abrasion, and R-value. Numerous samples are taken and analyzed prior to opening a pit, and the pit is subsequently resampled throughout its period of use. Published values of test

results in the Arizona Materials Inventory represent the average of many samples at a pit. These values are assumed to be representative of the river reaches where the pits occur, and therefore, give an idea of the general quality of sand and gravel materials in Arizona river reaches. Unfortunately, sediment sizes larger than 3-inches are excluded from the sample in ADOT sieve analysis. On cobble-bed channels, this causes a fairly substantial error in estimating the mean bed-material diameter and gradation coefficient. To supplement the ADOT sieve analysis, bed-material gradations reported in sediment transport studies conducted on Arizona rivers were included. These gradations are in close agreement with ADOT gradations on sand-bed rivers but differ significantly on cobble-bed channels. Sediment transport study gradations were used in place of ADOT gradations when they reported coarse fractions of bed material.

Using the published information in the Materials Inventory and with updated information supplied by the Materials Section Staff, an overview of the quality and quantity of sand and gravel resources in Arizona river reaches was compiled. Table 4.3 summarizes this overview of sand and gravel resource by physiographic region and for major river reaches within each region. The quantity estimate assumes single lift mining to a depth of 30 feet for the river width along the reach length.

4.2 Market Potential

In order to identify market potential, information was compiled on the construction industry economy, and on population growth in Arizona. Sources for this information include: Center for Business Research, Arizona State University; U.S. Department of Commerce, Bureau of Census; and the Arizona Department of Economic Security. The Center for Business Research monitors a group of economic indicators which has been published monthly since 1961. Population data from the Bureau of Census is compiled each decade. The Arizona Department of Economic Security has estimated population growth in Arizona for the next 50 years. A broad overview of the Arizona Economy was completed in 1986 by the Arizona Department of Commerce, which analyzed trends in a variety of areas in the economy.

Products derived from sand and gravel mining are utilized in a wide array of building materials such as concrete, asphalt paving, aggregate base coarse, concrete wall blocks, and many others. These building materials are fundamental to the construction industry. Keith (1969) notes that variations in the production of sand and gravel in Arizona are related to the changing levels of economic activity of the construction industry, which includes construction of new homes, city streets, urban arterial streets, freeways, private office and industrial buildings. Production is also influenced by the installation of

TABLE 4.3. Overview of Quality and Quantity of Sand and Gravel in Arizona Rivers
(Source: Arizona Materials Inventory, Arizona Department of Transportation,
Materials Services)

Region	River	Reach	Volume (million yd ³)	D ₅₀ (mm)	G	Type
Basin & Range	Gila	Confluence-Painted Rock	3432	3.2	5.8	Fine Gravel
		Painted Rock-Salt River	1783	3.0	6.8	Fine Gravel
		Salt River-Coolidge	3520	5.0	7.5	Fine Gravel
		Coolidge-Safford	2053	2.5	7.5	Fine Gravel
		Safford-headwaters	NI			
		Hassayampa	343	0.71	7.7	Coarse Sand
		Agua Fria	440	1.1	8.5	Coarse Sand
		New River	414	32	6.4	Coarse Gravel
	Salt	Confluence-Granite Reef	1100	96	6.7	Cobbles
	Santa Cruz	Confluence-Tucson	678	0.7	6.1	Coarse Sand
		Rillito/Pantano	281	0.86	5.8	Coarse Sand
		Tucson-Mogales	378	0.58	6.3	Coarse Sand
	San Pedro		718	1.1	8.7	Coarse Sand
	Bill Williams	Confluence-Alamo Lake	246	NP		
		Alamo Lake-headwaters	361 ¹	NP		
	Colorado	Border-Imperial	387 ²	NP		
		Imperial-Parker	959	NP		
		Parker-Davis	352 ³	NP		
		Davis-Hoover	(4)	NP		
		Hoover-Glen Canyon	(4)	NP		
Central Highland	Verde	Confluence-Bartlett	183		(5)	
		Horseshoe-Camp Verde	387		(5)	
		Camp Verde-headwaters	493	4.7	22	Fine Gravel
	Upper Salt	Roosevelt-headwaters	NI			
Colorado Plateau	Little Colorado	Confluence-Winslow	748	NP		
		Winslow-Holbrook	867	NP		
		Holbrook-headwaters	950	0.3	16	Fine Sand
	Puerco		1500	0.17	2.6	Fine Sand

NI = Material inventory not available

NP = No ADOT pits located in or near the river in this reach

1 = Exclude section flooded by Alamo Lake

2 = Exclude section flooded by Imperial Dam

3 = Exclude section flooded by Lake Havasu

4 = Within Grand Canyon

5 = Contains cobble sizes not measured in ADOT sieve analysis

major dams, highways, irrigation ditches, air fields, and defense establishments. Important projects that have stimulated sand and gravel production since World War II include the Federal Aid Highways Act of 1956, the Central Arizona Project, and Proposition 300 for freeway expansion in Maricopa County. With the exception of large public works projects, the demand for building materials generally follows the regional trend in population growth. The additional requirements of large public work projects must be estimated separately.

4.2.1 Regional Demand

4.2.1.1 Past Sand & Gravel Production

To obtain a historical perspective of market potential, data on prior sand and gravel production is reviewed along with associated data on construction activity including building permits and population growth. Figure 4.2 shows the historic increase of sand and gravel production for Arizona from 1947 to 1984. Over the 38-year production record, sand and gravel production has increased significantly but at a rate that reflects fluctuating economic cycles in the construction industry.

Production from 1947 to 1954 was fairly uniform but jumped dramatically in 1955 with introduction of the federal aid to highway program. The period from 1956 to 1961 saw steady above-average growth in the sand and gravel production, followed by a period from 1962 to 1970 of uniform or slightly declining production. Production increased rapidly from 1971 to 1973, followed by an equally rapid decline in 1974 and 1975. Production reached its highest level in 1979 but slumped to low levels by 1982, during the last economic recession. Recent production rates have increased rapidly, preliminary records for 1985 production indicate a record production level.

Keith (1969) summarizes statewide production from 1900 through 1966 and provides information on commercial and governmental production. Williams (1967) summarizes production data from the Tucson area from 1952 to 1966 and compares this data to population growth in the area. The Arizona Bureau of Geology and Mineral Technology in cooperation with the U.S. Bureau of Mines, compiles aggregate production data by county on an annual basis. Production data by county was reported in the Mineral yearbooks published from 1957 to 1975. Since 1975, only production data for Pima and Maricopa counties have been intermittently reported (1977, 1978, 1979, 1980 and 1982). Table 4.4 shows the relative portion of sand and gravel production for each county at five-year intervals beginning in 1960 and ending in 1975. During this period, production in Maricopa County consistently ranked the highest, accounting for 34 to 57 percent of total state production. From 1970, Pima County production has ranked second, accounting for 13 to 16 percent of total state

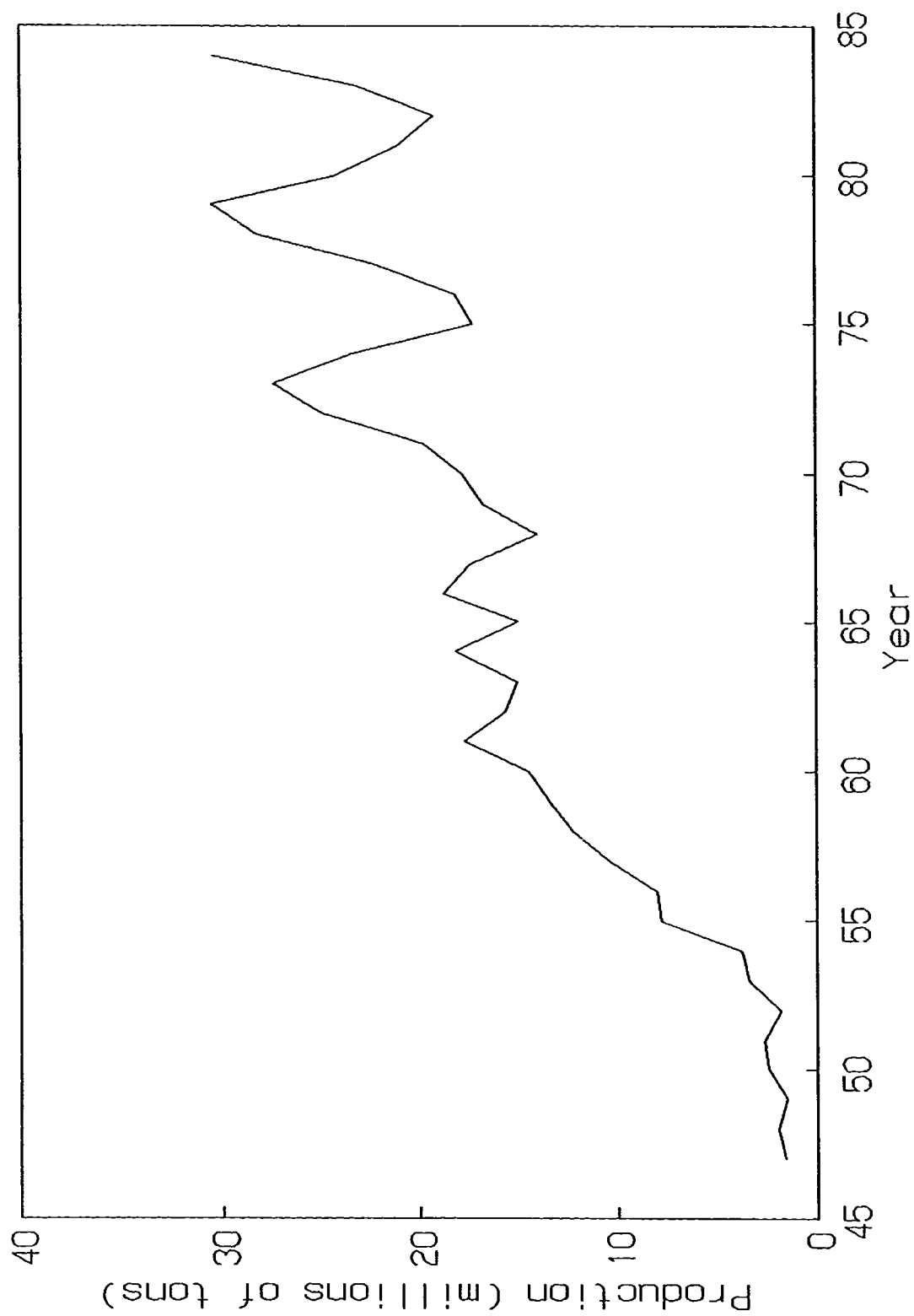


Figure 4.2. Sand and Gravel Production (1947-1984)

Source: Minerals Yearbook, U.S. Department of the Interior

TABLE 4.4. Sand and Gravel Production by County

<div> <div>(1960)</div> <div>Production</div> <div>‡</div> </div> <div>(X 10³ tons)</div>			<div> <div>(1965)</div> <div>Production</div> <div>‡</div> </div> <div>(X 10³ tons)</div>		
County			County		
Santa Cruz	5	0	Gila	93	1
Undist.	100	1	Greenlee	104	1
Graham	121	1	Apache	277	2
Mohave	139	1	Cochise	341	2
Gila	277	2	Yavapai	680	5
Navajo	315	2	Yuma	868	6
Yavapai	363	2	Undist.	1016	7
Apache	459	5	Navajo	1186	8
Yuma	595	6	Pima	1811	12
Pima	975	9	Pinal	1824	12
Cochise	1020	13	Mohave	1981	13
Pinal	1278	13	Maricopa	4737	32
Coconino	2863	14		14918	100
Maricopa	5980	34			
	14490	100			
<div> <div>(1970)</div> <div>Production</div> <div>‡</div> </div> <div>(X 10³ tons)</div>			<div> <div>(1975)</div> <div>Production</div> <div>‡</div> </div> <div>(X 10³ tons)</div>		
County			County		
Gila	141	1	Apache	37	1
Cochise	168	1	Santa Cruz	55	1
Undist.	214	1	Greenlee	173	1
Santa Cruz	287	2	Graham	176	1
Navajo	358	2	Gila	294	2
Mohave	477	3	Cochise	312	2
Yavapai	756	4	Pinal	482	3
Pinal	1736	10	Yavapai	603	4
Coconino	1853	10	Mohave	620	4
Yuma	2546	14	Navajo	624	4
Pima	2923	16	Yuma	631	4
Maricopa	6363	36	Coconino	1031	6
	17822	100	Pima	2286	13
			Maricopa	9897	57
				17222	100

production. In 1975, Maricopa and Pima counties accounted for 70 percent of total state production and in 1980, the two counties accounted for 76 percent. In 1975, Coconino County's production ranked third at about one-half the production of second ranked Pima County, accounting for six percent of total state production. Yuma, Navajo, Mohave and Yavapai each produced four percent of total state production in 1975. All remaining counties cumulatively had less than eight percent of total state production in 1975.

A gradual increase in Maricopa County production relative to other counties in the state is evident. In the period from 1960 to 1970, Maricopa County accounted for about one-third of total state production. Production levels since 1975 are approaching two-thirds of state production.

Historic data since 1960 indicates that county production of sand and gravel can be grouped into the following categories:

- * Very High Production - Maricopa County (60% of total state production)
- * Moderate Production - Pima County (10-15% of total state production)
- * Low Production - Coconino, Mohave, Navajo, Pinal, Yavapai and Yuma (3-6% of total state production)
- * Very Low Production - Apache, Cochise, Gila, Graham, Greenlee, La Paz and Santa Cruz (less than 3% of total state production).

4.2.1.2 Construction Activity

Data on housing units authorized by building permits is published by the U.S. Department of Commerce, Bureau of Census. This data was reviewed for the period from 1955 to 1985. The historic increase in the number of building permits issued during this period for the State of Arizona is shown in Figure 4.3. There are interesting similarities and differences between sand and gravel production and the issuance of building permits. From 1955 to 1961, there was a 128 percent increase in the production of sand and gravel, but only a 42 percent increase in building permits. As was mentioned previously, a strong demand for sand and gravel was created during this period as a consequence of the initiation of the federal aid highway program. From 1961 to 1970, there was steady or lower demand for sand and gravel. During this time, home building was initially steady, but slumped during the mid and late 1960s. Economic activity accelerated in the early 1970s and both permits issuance and sand and gravel production increased. Building permits peaked in 1972, one year before sand and gravel production, indicating about a one-year lag between the time a permit is issued and actual construction. Building permits and sand and gravel production hit lows in 1975, followed by a period of increased construction activity with

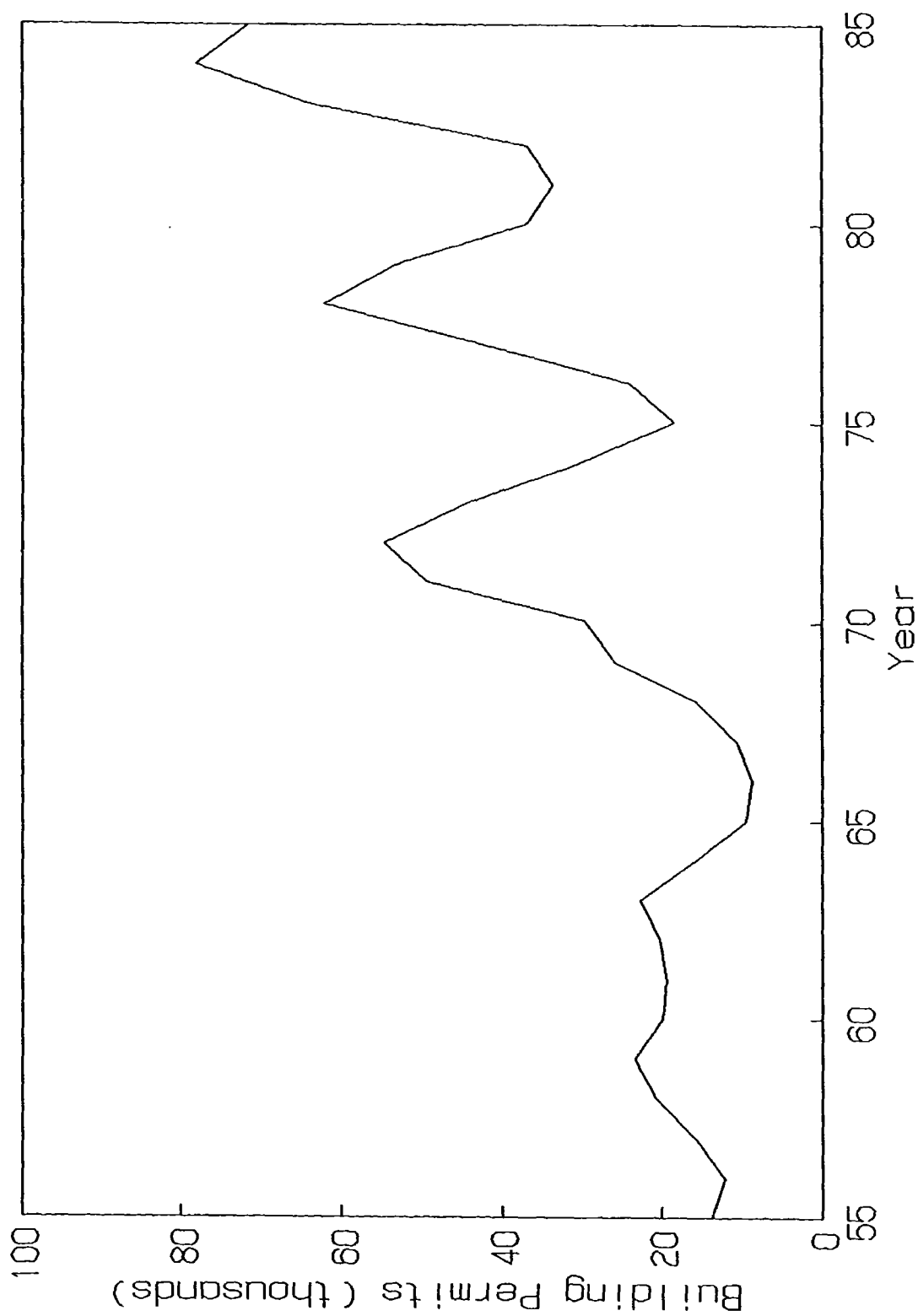


Figure 4.3. Building Permits in Arizona (1955-1985)

Source: U.S. Department of Commerce, Bureau of the Census

building permits peaking in 1978 followed one year later by a peak in sand and gravel production. Building permits issuance hit lows in 1980 to 1982, which coincides with low production in the sand and gravel industry in 1982.

This review of construction history indicates that sand and gravel production in Arizona has two primary markets: one being road building; the second being residential, commercial and industrial building. Commercial construction includes construction of apartment, office building, retail and motel/hotel. This sector of the construction industry has been a leading area of activity in recent years, particularly apartments (Ronan, 1986). The economic behavior of commercial and residential construction are similar, with the data on residential home building permits being indicative of the entire commercial/residential construction market. It has been estimated by others (Keith, 1969) that road building consumes approximately one-third of sand and gravel production. Information on the rate of consumption for road building is limited, but is assumed to be more uniform. This implies that the fluctuations in sand and gravel production are associated with residential, commercial, and industrial construction.

Population growth is a primary factor in sand and gravel demand. The demand for new homes, apartments, office buildings, roads, and major infrastructure projects arises from population growth and the ensuing economic activity. Figure 4.4 shows the growth in Arizona population from 1960 to 1985. Two periods in population growth are evident from this graph: in the decade of the 1960s population grew 34 percent, adding 439,000 people; and in the decade of the 1970s population grew at a much faster rate, 49 percent, adding 863,000 people. From 1980 to 1985, Arizona's population has grown at the rate of 82,000 people per year, about the same rate as during the 1970s.

Per capita consumption of sand and gravel for the increase in Arizona population in the 1960s was 105 tons/person, and in the 1970s was 103 tons/person. Consumption in the 1980s is running at 101 tons/person. There was one building permit issued for every 2.6 additional persons during the 1960s and for every 2.1 additional persons during the 1970s. Permitting for residential construction in the 1980s is running at one unit for every 1.6 additional persons. These statistics indicate two countervailing trends in the construction industry: a reduction in the amount of sand and gravel used in construction; and second an increase in the number of housing units per capita. The reduction in the amount of sand and gravel used reflects a wider range of construction methods in addition to the predominant use of concrete block wall. Also, road construction methods have incorporated recycling of pavement which has reduced the demand for aggregate. The increase in housing units per capita indicates a trend toward smaller households.

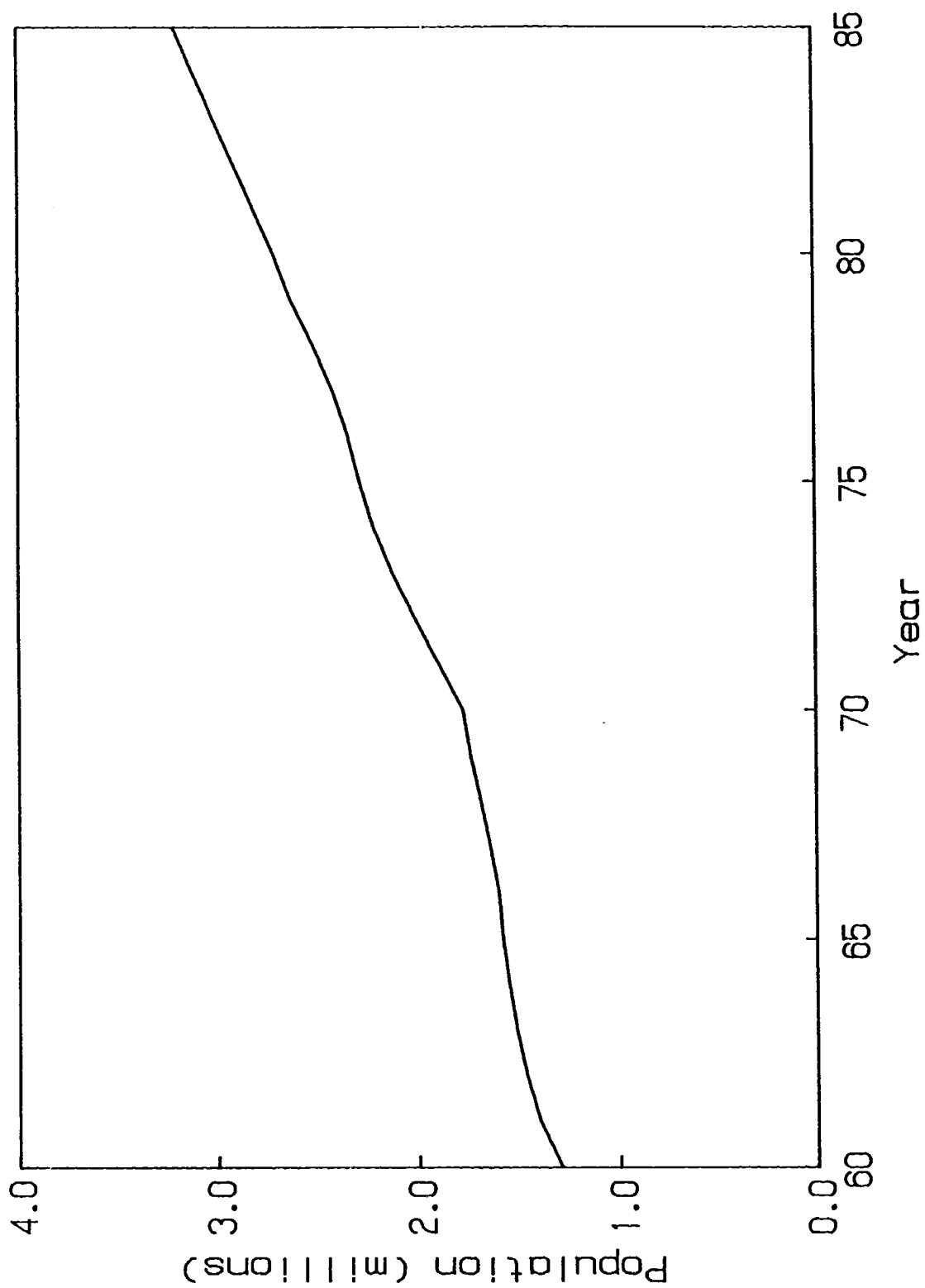


Figure 4.4. Arizona Population Growth (1960-1985)

Source: Arizona Statistical Review

An estimate of future per capita consumption in the face of these trends is somewhat speculative. There is little doubt that sand and gravel will continue to be a basic raw material for road construction and for products used in residential, commercial and industrial construction. The 1980s per capita consumption is considered to provide a reasonable guide to a lower limit of sand and gravel consumption. The 1970s per capita consumption is used as the best estimate of average sand and gravel consumption. The 1960s per capita consumption is taken as an approximate upper limit of sand and gravel consumption. This gives the following bounds for annual per capita consumption of sand and gravel in Arizona:

Lower bound: 10.1 tons/person/year
Mean : 10.3 tons/person/year
Upper bound: 10.5 tons/person/year

In order to account for intensified freeway construction activity within Maricopa County during the twenty-year period beginning in 1985, 1.5 tons/person/year has been added to the mean annual per capita consumption rate for all of Arizona (10.3 tons/person/year). As a result, for Maricopa County only, the mean annual per capita consumption rate is estimated to be 11.8 tons/person/year.

4.2.2 Projected Sand and Gravel Production

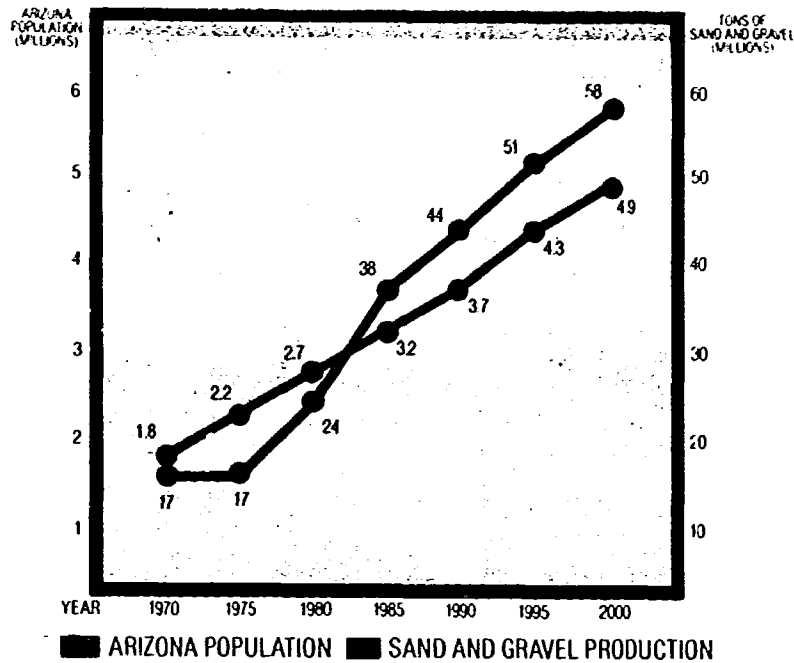
The COE (Los Angeles District, 1981) estimated the demand for aggregate resources in the Phoenix area as a function of the following parameters:

$$D = 10.3 + 0.59M + 3.11C + 0.38E$$

where D is the estimated annual demand (tons), M is the annual miles of roads constructed, C is the annual number of commercial-building permits issued, and E is the annual number of workers employed in construction.

The Arizona Rock Products Association (1986) has estimated demand for sand and gravel to the year 2000, (see Figure 4.5). This estimate anticipates that demand for rock products will outpace Arizona population growth through the end of the century. Production of sand and gravel is expected to reach 58 million tons per year by the year 2000, compared to 1985 production of 38 million tons. They also estimate that construction of planned freeways in the Phoenix metropolitan area will require 14.5 million tons of sand and gravel, and 8.8 million cubic yards of concrete.

Using forecasted population growth for the next 50 years for Arizona counties, an estimate of ten-year sand and gravel consumption rates is made. Table 4.5 summarizes sand and gravel consumption by county at ten-year intervals. State production of



SOURCE: ARIZONA DEPARTMENT OF ECONOMIC SECURITY AND U.S. BUREAU OF MINES

Figure 4.5
Arizona Population and Sand and Gravel
Production:
1970-2000

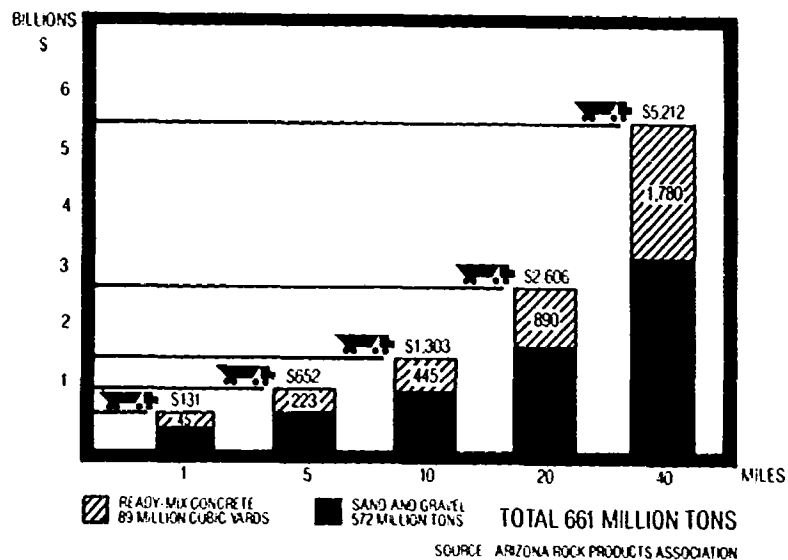


Figure 4.7. Transportation Costs.

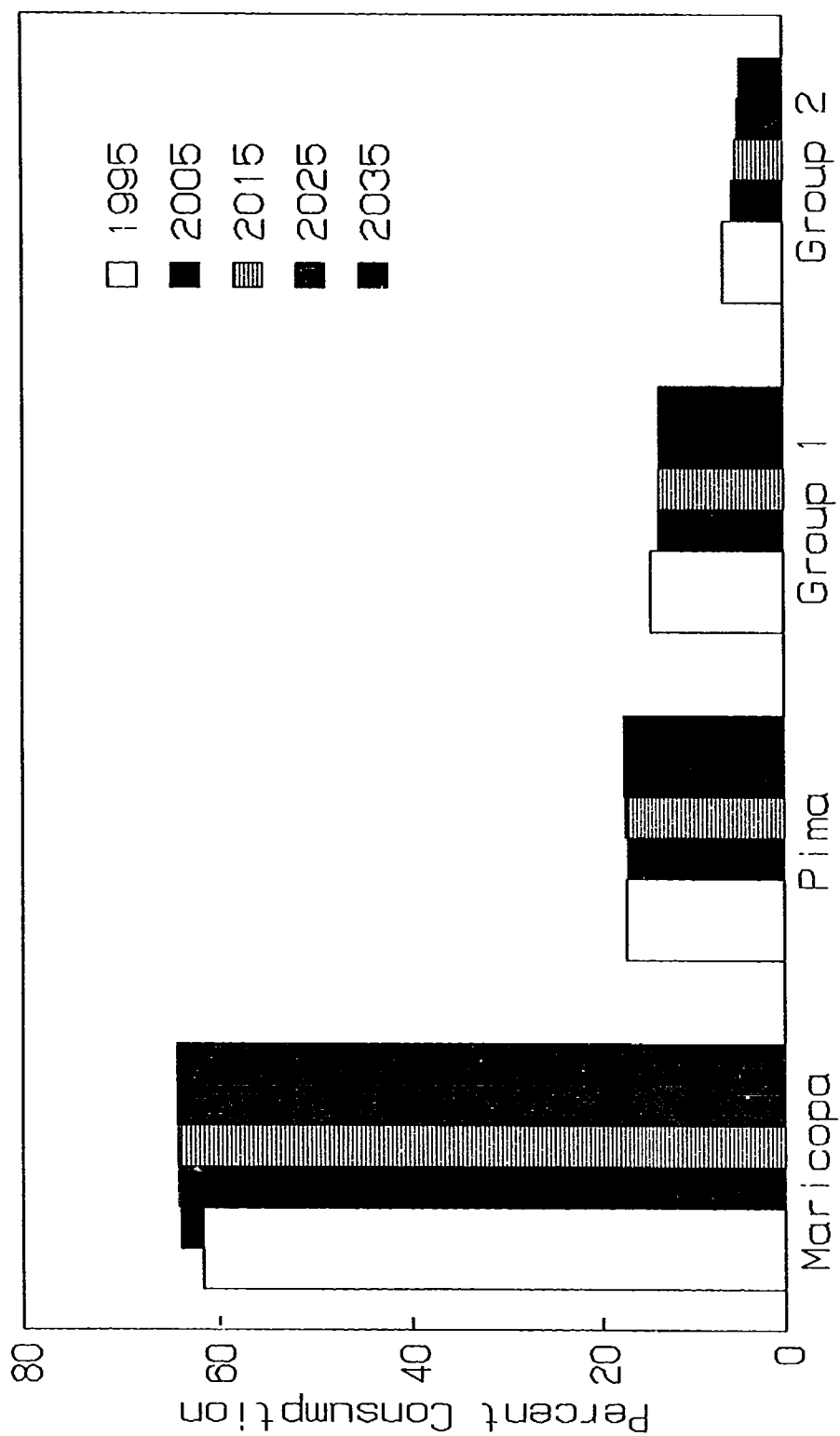
sand and gravel based on forecasted population growth ranges from 440-million tons/decade to 1.1-billion tons/decade. The population forecast anticipates some demographic changes throughout Arizona over the next 50 years. Maricopa County's growth will result in the highest production of sand and gravel. Overall, Maricopa County will result in up to 62 percent for the total state production through 1995, and then average 64 percent through 2035. Pima County's production is expected to reach 17 percent by 1995 and increase to 18 percent through 2035. Together, Maricopa and Pima counties are projected to account for 79 to 82 percent of total state production through 2035. Production rates in Cochise, Coconino, Mohave, Pinal, Yavapai and Yuma are expected to account for fifteen percent of production by 1995 and decrease to 13 percent by 2035. Figure 4.6 graphs the percentage of consumption of sand and gravel by county from 1985 to 2035.

TABLE 4.5. Forecasted Sand and Gravel Production, 1986 to 2035
(Based on population forecasts Arizona Department of Economic Security, 1986)

County	Ten-Year Production Rates (thousand tons)				
	1995	2005	2015	2025	2035
Apache	7056	8683	10305	11984	13601
Cochise	11279	13380	15867	18463	20945
Coconino	10542	13442	16949	20652	24159
Gila	4352	4712	5387	6062	6690
Graham	2786	2750	2961	3198	3414
Greenlee	958	958	979	1009	1030
La Paz	1468	1679	1906	2148	2369
Maricopa	269955	379754	478915	577303	676470
Mohave	8750	11273	14142	17165	20034
Navajo	8786	10254	12082	13957	15790
Pima	76014	100940	128652	157142	184854
Pinal	12123	15445	19189	23046	26785
Santa Cruz	3095	4105	4990	5902	6788
Yavapai	10717	14585	19385	24421	29221
Yuma	10207	12216	14801	17484	20064
Total	438088	594176	746510	899936	1052214

4.3 Market Value

Williams (1967) notes the following about sand and gravel unit prices, and their relation to supply and demand. "When production of sand and gravel is high because of demand, competition among operators is keen and sale prices are usually lower. In addition, higher volume lowers unit production costs and permits profitable operation at a smaller unit profit. Fixed



Group 1: Cochise, Coconino, Mohave, Pinal, Yavapai, Yuma

Group 2: Apache, Gila, Graham, Greenlee, La Paz, Navajo, Santa Cruz

Figure 4.6. Percent Consumption by County (1995-2035)

costs can be spread out and charged to more tons at a lower rate."

The COE (Los Angeles District, 1981) performed a price trend analysis for sand and gravel in the Phoenix area, which gave the following equation:

$$P_t = 1.03 + 0.065t - 0.027t^2 + 0.0029t^3$$

where P_t is the estimated price (\$/ton), and t is the cumulative time in years since 1965. The price trend analysis was based on sand and gravel prices from 1965 to 1981. The Corps study reported a 1981 sand and gravel price of \$6.80/ton.

The Arizona Rock Products Association (1986) reports a 1985 market value of statewide sand and gravel production of \$122.9 million. The value of Arizona production is also reported by the Arizona Bureau of Geology and Mineral Technology in the Mineral Yearbook. The value of output per sand and gravel worker in 1985 was \$80,900. This compares to an output of \$80,500 per worker in the Arizona electronics industry.

4.3.1 Transportation Costs

Because of the weight of sand and gravel products, and the perishability of concrete, transportation is a major portion of the cost (Arizona Rock Products Association, 1986). Research shows that the additional cost paid for sand and gravel products and ready-mix concrete increases rapidly with transportation distance (Figure 4.7). Most major river reaches in Arizona are paralleled by transportation routes but in some cases, reaches exist that are relatively inaccessible. River reaches that are accessible usually only have a portion of their length that is within a reasonable haul distance of an urban market. Table 4.6 summarizes access and haul distance information for the selected major river reaches in Arizona. Access was considered poor if the river reach was not paralleled by a major transportation route or frequently crossed by a series of routes. The percentage of the reach within reasonable haul distance was determined by measuring a ten-mile radius around all cities in the reach which issued more than 100 residential building permits in 1985.

4.3.2 Employment

Employment statistics compiled by the Arizona Rock Products Association (1986) indicates the very fundamental role that sand and gravel production plays in the construction economy of Arizona. Figure 4.8 shows the relationship between workers in the sand and gravel industry and other workers in the construction industry. The 1,519 sand and gravel workers create essential materials that support an additional 79 jobs (per sand

TABLE 4.6. Access and Haul Distance for Selected River Reaches

Region	River	Reach	Market	Total Length	Marketable Length	Percent Marketable	Percent Urban
Basin & Range	Gila	Confluence-Painted Rock	Yuma	117	6.5	5.5	0
		Painted Rock-Salt River	Yuma/Metro Phx	61	27.5	45.0	0
		Salt River-Coolidge	NM	120	-	-	0
		Coolidge-Safford	NM	70	-	-	0
		Safford-headwaters	NM	LA	LA	-	0
		Hassayampa	Wickenburg	86	18	21	0
		Agua Fria	Avondale	50	24	48	12
		New River	Peoria	47	16.5	35	11
	Salt	Confluence-Granite Reef	Metro Phoenix	38	35	93	43
	Santa Cruz	Confluence-Tucson	Tucson	77	17	22	4
		Rillito/Pantano	Tucson	40	19	48	35
		Tucson-Nogales	Tucson/Nogales	43	27.5	64	7
	San Pedro		Sierra Vista	82	10	12	0
	Bill Williams	Confluence-Alamo Lake	NM	LA	LA	-	0
		Alamo Lake-headwaters	NM	LA	LA	-	0
	Colorado	Border-Imperial	Yuma	35	20	57	9
		Imperial-Parker	NM	LA	LA	-	0
		Parker-Davis	NM	LA	LA	-	0
		Davis-Hoover	NM	LA	LA	-	0
		Hoover-Glen Canyon	NM	LA	LA	-	0
Central Highland	Verde	Confluence-Bartlett	Metro Phoenix	21	12*	60*	0
		Horseshoe-Camp Verde	NM	LA	LA	-	0
		Camp Verde-headwaters	NM	56	-	-	2
	Upper Salt	Roosevelt-headwaters	NM	LA	LA	-	0
Colorado Plateau	Little Colorado	Confluence-Winslow	NM	LA	LA	-	0
		Winslow-Holbrook	NM	-	-	-	2
		Holbrook-headwaters	NM	108	-	-	0
	Puerco		NM	170	-	-	0.6

LA = Limited access

NM = No local market

* = Includes land on Indian Reservation

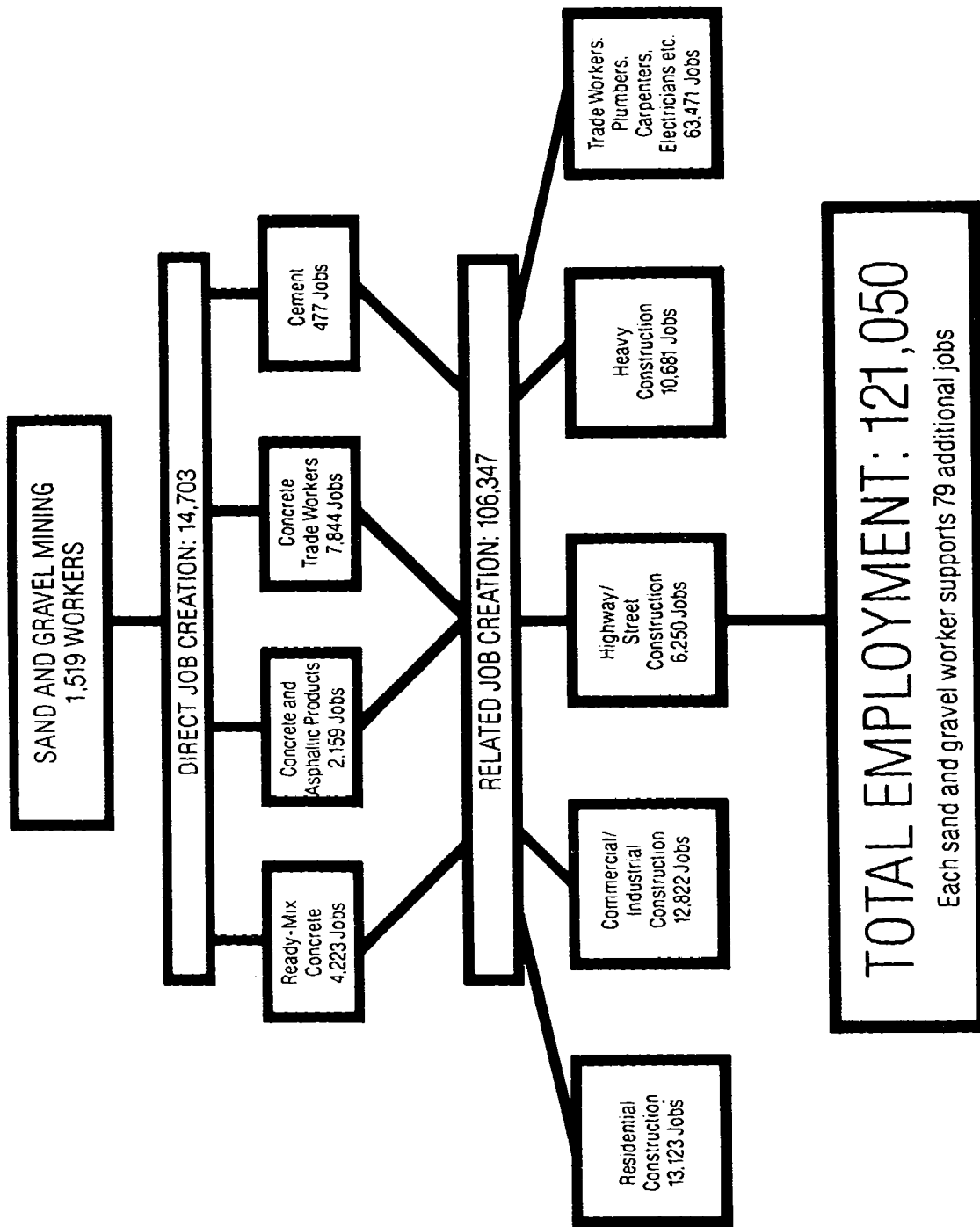


Figure 4.8. Sand and Gravel Employment and Related Construction Industry Jobs.

(after Arizona Rock Products Association, 1986)

and gravel worker) in the construction sector of the Arizona economy. The construction industry as a whole results in the creation of other jobs in the service, finance and trade sectors of the economy.

The total 1985 payroll for the sand and gravel industry and various affiliated and related industries approached \$2.4 billion. Table 4.7 summarizes the 1985 payrolls for these industries.

TABLE 4.7. Payroll in Sand and Gravel and Related Industries
(Source: Arizona Rock Products Association, 1986)

Sand and Gravel Mining	\$ 28,600,000
Ready-Mix Concrete	98,400,000
Concrete and Asphaltic Products	44,500,000
Concrete Trade Workers	172,600,000
Cement	14,000,000
Residential Construction	231,200,000
Commercial/Industrial Construction	276,000,000
Highway/Street Construction	153,600,000
Heavy Construction	308,200,000
Building Trade Workers	1,063,000,000
TOTAL PAYROLL	\$2,390,100,000

4.3.3 Taxes and Fees Paid

The sand and gravel producers are taxed on their investments in land, machinery, and transportation equipment. Property taxes and vehicle fees for 1985 totalled nearly \$9 million (Arizona Rock Products Association, 1986). In addition, income, corporation, unemployment and sales taxes amounted to \$36.5 million.

V. SOCIAL AND ENVIRONMENTAL FACTORS

5.1 Land Use Conflicts

Sand and gravel mining is an industrial land use and, as such, may conflict with adjacent non-industrial land uses. As with other industrial land uses, sand and gravel mining has operational activities that are considered a nuisance to commercial or residential land uses. Nuisance issues include visual setting, dust in the air, noise of machinery and equipment on site, as well as the effects of truck traffic on flow of local traffic and the frequency of street repairs. Unfortunately, data on these nuisance-level impacts is not generally available.

It is assumed that in areas experiencing urban growth, land-use conflicts will be more likely to occur. These conflicts arise because urban development results in commercial and residential developments on land adjacent to industrial sites. Population growth in urban areas is considered to be a general indicator of potential land-use conflicts. Data on population trends is considered to be the best indicator of social impacts created by sand and gravel mining operations.

It is assumed that river reaches within city boundaries have a strong potential of encountering some conflicts with adjacent land uses. Table 4.6 shows the percentage of a river reach that is within a marketable distance of an urban area that is within urban boundaries. The urban areas associated with metropolitan Phoenix and Tucson have the largest potential for land-use conflicts.

5.2 Proximity to Wildlife Habitat

Data on social and environmental conditions in Arizona are limited. The primary environmental data of interest is the location of riparian and wetland habitat in Arizona. River reaches with perennial and intermittent flows, either natural, regulated or man-induced from waste-water discharges are taken as an indicator of riparian habitat. Sources of data on riparian habitat include the U.S. Fish and Wildlife Service and the Arizona Game and Fish Department. Formal classification and mapping of riparian habitat has not been undertaken for rivers in Arizona. Standards are still under consideration, and actual mapping is probably several years from initiation. The U.S. Fish and Wildlife Service has mapped wetland areas in Arizona at a scale of 1:100,000. In 1981, The Arizona Game and Fish Department published a map of perennial streams and some important wetlands. The perennial-stream information is presented on a U.S.G.S. state base-map at a scale of 1:1,000,000. It was assumed that the amount of riparian and wetland habitats in a river reach provides an indicator of other environmental issues, such as the presence of threatened or endangered species.

It is recognized that habitat resources in the desert environment of Arizona are complex. Ephemeral reaches may provide dynamic habitat that flourishes briefly between dry periods. Likewise, man created habitat may also play a role in providing riparian habitat. Table 5.1 summarizes the relative percentages of perennial and ephemeral reaches of the selected river reaches.

5.3 Noise, Dust, and Visual Pollution

Social impacts to a river reach include air, noise, and water-pollution effects, along with a number of land-use and infrastructure conflicts. A study of the impact of the sand and gravel mining industry on air, noise, and water quality has not been conducted in Arizona. In lieu of such an analysis, it is not known if noise or dust levels at sand and gravel mining operations violate pollution standards. To the extent that noise and dust levels are a nuisance to adjacent property owners, this issue can be classed as a land-use conflict. The same is true of visual resources.